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DEVELOPMENT OF A WELD QUALITY MONITOR

by J. G. Etzel and J. A. Munford

Goddard Space Flight Center
Greenbelt, Md.

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ABSTRACT

An investigation was performed to develop a nondestructive method of evaluating cross-wire resistance-welded joints used in electronic packaging. Mechanical strength and reproducibility of strength were determined for several alloy combinations. Data indicated that an optimum degree of embedment exists for each combination of materials. This report describes the development of an electromechanical device that automatically measures and displays the embedment of each welded joint and "locks out" the welding machine if the embedment value is not within preset upper and lower limits.

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INTRODUCTION

Welded electronic circuitry is a widely accepted method of packaging flight hardware for satellite and sounding rocket applications. The welded module, in the cordwood configuration, offers high-density packaging with bond strengths several times greater than solder connections. Further advantages of welded circuitry are lighter weight, reduction of outgassing, elimination of damage to temperature-sensitive components, and, most importantly, higher reliability. These advantages, however, have been offset somewhat by the difficulty in determining the integrity of the welded connection. Joints are normally evaluated on the basis of their mechanical strength and visual appearance. Since mechanical strength data are not obtainable on actual production joints, statistical quality control and visual inspection have become the standard methods of determining production weld integrity.

Thus, acceptance usually depends on a judgment of the external appearance of the finished joint. This method cannot be expected to yield highly reliable connections since the criteria for visual examination generally involve only a search for external defects. There was, therefore, a need for a method of determining the parameters of finished welded joints that could be measured directly and that were indicative of quality. Several methods were investigated; the most successful was found to be the measurement of the correlation between the degree of embedment and weld strength.

CORRELATION OF EMBEDMENT TO QUALITY

More than 8000 weld samples were prepared at various electrode force and weld energy settings on a single-pulse, capacitor-discharge machine having only two controlled variables, weld energy and electrode force. This is the type of machine most commonly used today. The average tensile-shear strength, standard deviation in strength, and embedment were determined for seven common alloy combinations at each combination of welder settings. The "embedment," or "set-down," is defined as the reduction in thickness of the joint members as a result of the welding operation. For the purpose of this investigation, it must also include the small surface indentations produced by the electrodes.

Tests to correlate embedment with strength indicate that two general types of relationships occur, depending upon the alloy combinations. Most commonly, the strength increases with increasing embedment until peak strength is attained, after which the strength steadily decreases. Figure 1 illustrates this behavior. Some material combinations, notably nickel welded to nickel, produce steadily increasing average strength levels as the embedment is increased. No maximum strength is apparent, as illustrated in Figure 2, even at embedment levels where electrode sticking and spitting occur. A minimum deviation in strength, however, occurs at a strength level somewhat below the maximum, and this embedment level should dictate the optimum embedment. For all material combinations encountered, the standard deviation decreases as embedment is increased until a minimum standard deviation is reached. Greater embedment values produce greater standard deviations, as illustrated in Figure 3. When these relationships have been established

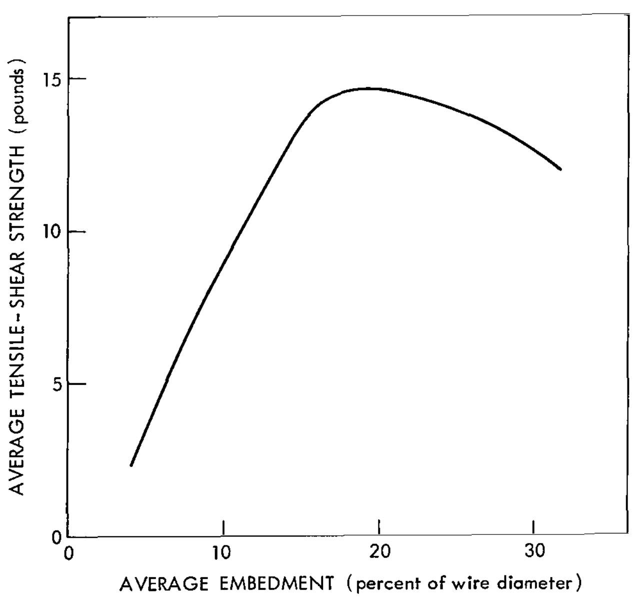


Figure 1–Strength-embedment relationship typical of most materials.

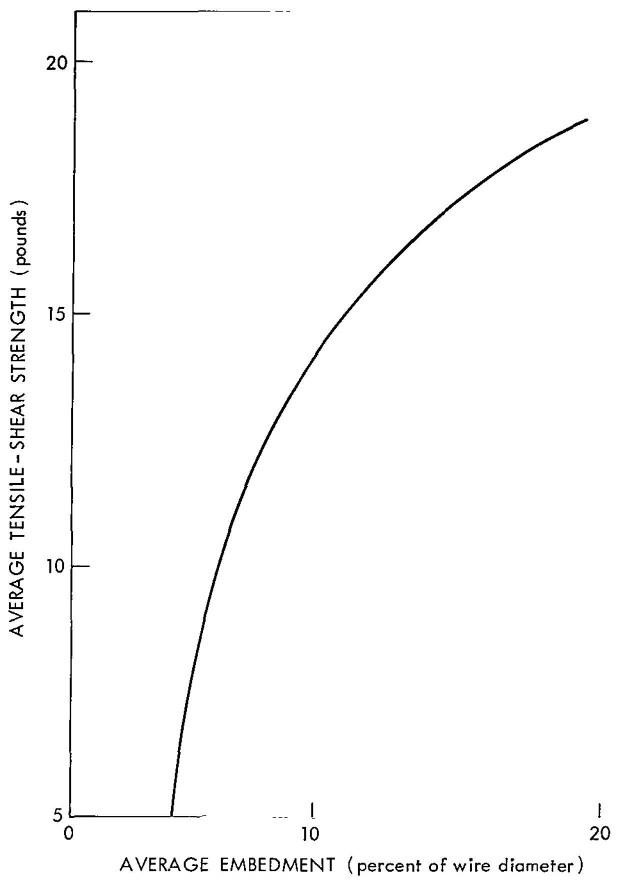


Figure 2–Strength-embedment relationship typical of nickel 200 welded to nickel 200.

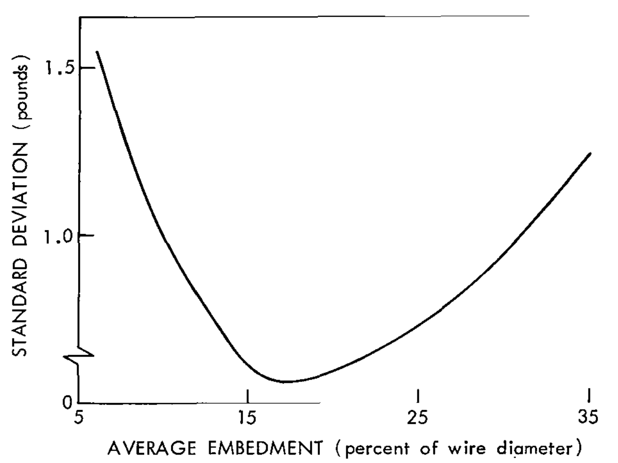


Figure 3–Standard deviation-embedment relationship typical of most materials.

for a particular combination of alloys, an optimum value of embedment can be determined with upper and lower embedment limits corresponding to acceptable strength and consistency limits. A system was devised by which electrode tip movement is sensed and used as a measure of embedment as the joint is produced.

A proof-of-principle model monitoring system was fabricated; more than 1200 weld samples were produced, and the embedment monitored at various energy and force settings. It was found that faulty joints could be discovered by this method. As a result of this success, a contract was negotiated with the Neotec Corporation, Rockville, Maryland, to modify and improve the system and to fabricate a working model.

CIRCUIT DESCRIPTION OF MONITORING SYSTEM

A monitoring system was then developed with the automatic features necessary for use on a production line. It included the capability of presetting the upper and lower limits and automatically locking out the welding machine after a joint was rejected to prevent the operator from inadvertently producing more faulty joints. The monitor can be equipped with a key-operated switch that can be unlocked only by selected quality control or supervisory personnel.

The basic embedment measurement is made with a linear voltage displacement transducer (LVDT). Figure 4 shows the mechanical coupling between the LVDT and the welding head on a pincer-type welder. As shown, the LVDT actuator and the moveable electrode pivot on the same shaft. The radius of rotation is also the same, resulting in a one-to-one relationship between weld tip motion and the LVDT plunger assembly travel. The actual embedment measurement is made by storing the LVDT output voltage just before welding and subtracting the final LVDT output after the weld has been made. This voltage difference is proportional to the distance traversed by the weld tip during the weld process and, in turn, is proportional to the weld embedment. The weld quality monitor consists of five functional sections as shown in the schematic diagram (Figure 5).

1. Power supply
2. LVDT driver
3. Control flip-flop
4. Embedment measurement
5. Go/No Go logic

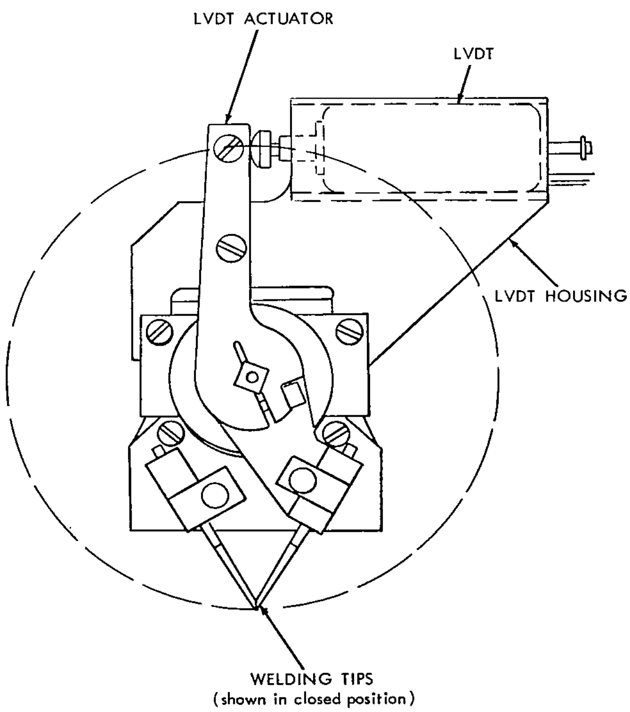
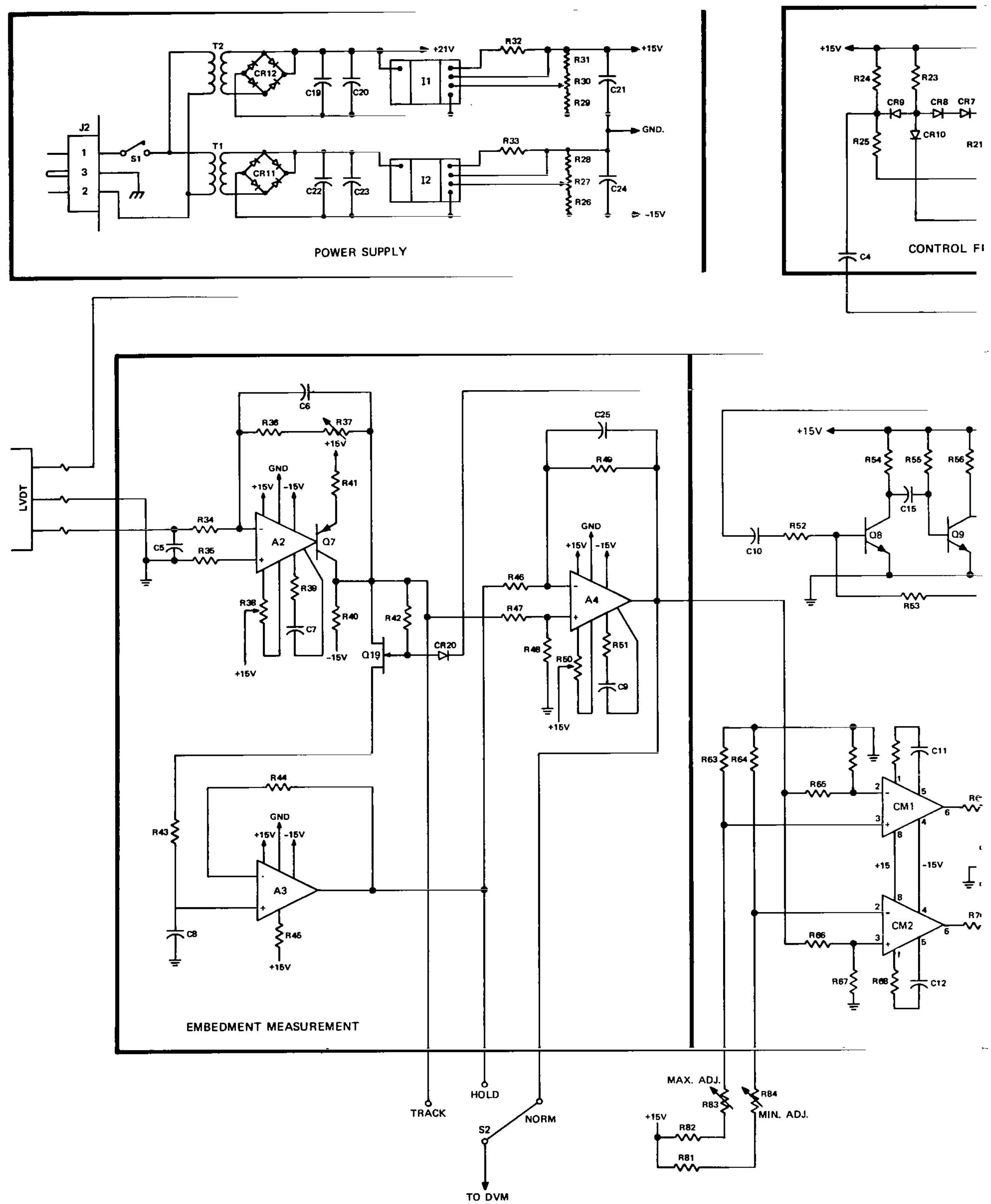


Figure 4—Mechanical coupling of linear voltage displacement transducer (LVDT) to pincer-type welder head.


POWER SUPPLY
CONTROL F
EMBEDMENT MEASUREMENT
LVDT
TRACK
HOLD
NORM
S2
TO DVM
MAX. ADJ.
MIN. ADJ.
+15V
-15V
+21V
GND.
J2
S1
T1
T2
CR11
CR12
I1
I2
A2
A3
A4
Q7
Q8
Q9
Q19
CM1
CM2

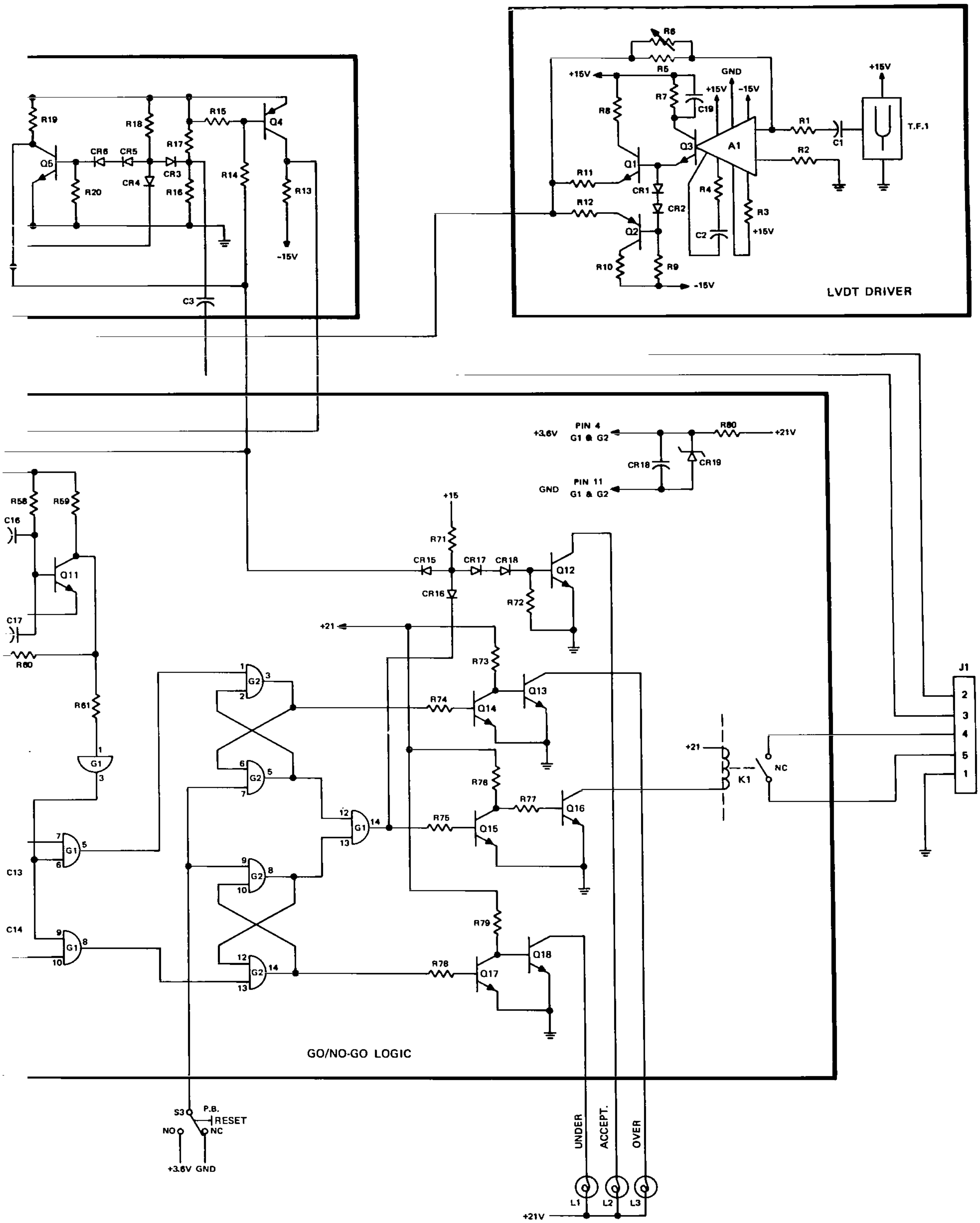


Figure 5. Schematic of Monitoring System

Power Supply

Two highly regulated dc voltage sources are required in the weld quality monitor. Two isolated, unregulated dc voltages are obtained from a circuit consisting of two transformers, diode rectifier bridges, and filter capacitors. These voltages are inputs to two precision, integrated-circuit voltage regulators (I1 and I2) that provide highly regulated ±15 volts dc. Resistors R32 and R33 limit the output current of each regulator to 0.5 amp, and trim resistors R27 and R30 provide fine adjustment of each output voltage.

LVDT Driver

The LVDT is driven from a 1.05-kHz low-impedance circuit. The circuit consists of a tuning fork oscillator buffered by a modular operational amplifier and an output driver. Transistors Q1, Q2, and Q3 form a push-pull output driver that delivers the required power to the LVDT. Crossover distortion is virtually eliminated at the output by including the push-pull driver within the feedback loop of the modular amplifier. Trim resistor R6 is used to adjust the peak-to-peak output voltage swing to 12 volts.

Control Flip-Flop

The control flip-flop synchronizes weld quality monitor operation to the welder. Its set and reset inputs are derived from the microswitch internal to the welder, which controls the shorting relay. The sequence of events is as follows:

1. The flip-flop is set following depression of the weld lever.
2. The weld current is developed approximately 100 milliseconds later.
3. The flip-flop remains set until the weld lever is released, which resets the flip-flop.

Embedment Measurement

Embedment is measured by means of the LVDT output, a dc signal proportional to the relative position of its plunger assembly. This signal is amplified by A2. Trim resistor R37 is used to adjust the gain of this amplifier to yield 50 millivolts for 0.001 inch of travel of the LVDT plunger assembly. The amplified signal feeds a field effect transistor (FET) switch (Q19), which is normally conducting (control flip-flop in reset state). In this condition, capacitor C8 is charged to the output voltage of A2. Amplifier A3 is an ultrahigh-input-impedance voltage follower whose output voltage is the same as the voltage on C8. When the control flip-flop changes state, the FET switch is opened, isolating the voltage on C8, and the voltage continues to appear at the output of A3. This voltage feeds the negative input of A4 while the output of A2 feeds the positive input of A4. The output of A4 is therefore proportional to the difference in voltage between the two input amplifiers (A2 and A3). Since the output of A2 is proportional to the final position of the LVDT plunger assembly after the weld is made and the output of A3 is proportional to the position of the plunger assembly just before the weld, the output of A4 is proportional to the amount of weld embedment. Amplifier A4 has a fixed gain of 10 so that its output voltage is 0.5 volt per 0.001 inch of embedment.

Go/No Go Logic

The Go/No Go logic consists of steering logic, two comparator circuits (C1 and C2), and two one-shot multivibrators. Transistors Q8 and Q9 form the first one-shot, which is triggered by the control flip-flop when it changes to the set state. The time constant of this circuit is 200 milliseconds, which is greater than that required by the welder to make a weld. At the end of the 200-millisecond period, a second one-shot (Q10, Q11) is triggered; its time constant is 20 milliseconds. This period is the sample time during which it is determined whether the resultant weld embedment is within the maximum and minimum preset limits.

Comparator CM1 determines if the amount of weld embedment exceeds the maximum preset limit. Its inputs are the embedment signal from the output of A4 as its negative input and the output from R83 as its positive input. Before the weld is made, the output of A4 is zero, and the potentiometer voltage is a positive voltage proportional to the position of the wiper arm. The position of the wiper is adjusted by a dial on the front panel. If the output of A4 exceeds the voltage on the wiper after a weld is made, then the output of CM1 changes from a positive voltage to a negative voltage.

In like manner, CM2 yields a negative voltage at its output when the amount of weld embedment is less than the preset minimum embedment limit. This is accomplished by means of the positive and negative inputs of CM2 from the output of A4 and the wiper arm of R84, respectively.

Two AND gates sense a negative output from either CM1 or CM2. The other input to each of these gates is the 20-millisecond one-shot multivibrator signal, which occurs 200 milliseconds after the weld is made. If an over- or under-embedment condition exists, the corresponding AND gate output changes state.

This action sets a corresponding flip-flop, thereby storing the fault condition. The output of each flip-flop energizes a light driver which, in turn, operates a front panel indicator that displays an over- or under-embedment condition. In addition, the output of each flip-flop feeds an OR gate whose output drives relay K1. This relay disables the welder by opening the charging circuit. The welder is enabled by resetting the set flip-flop. This is done by depressing pushbutton switch S3 located on the front panel.

If the amount of weld embedment falls between the minimum and maximum limit, then the "Acceptable" light appears. This is accomplished by AND gate Q12, which receives as its input the inverted OR gate output and the set side of the control flip-flop. In this manner, the "Acceptable" light is lit when the welder control lever is depressed and the embedment signal is between the preset minimum and maximum embedment limits.

Figure 6 shows the weld quality monitor adapted to a commerical welder with a pincer-type welding head. An additional system using a slightly modified mechanical coupling was developed for use with opposed-electrode welding heads (Figure 7).

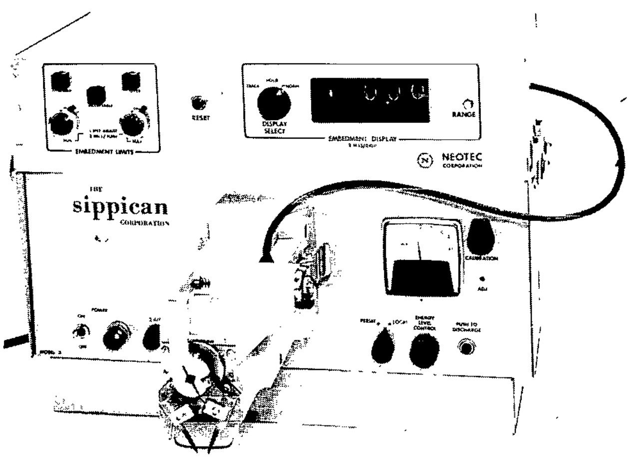


Figure 6—Weld quality monitor attached to pincer-type welding head.

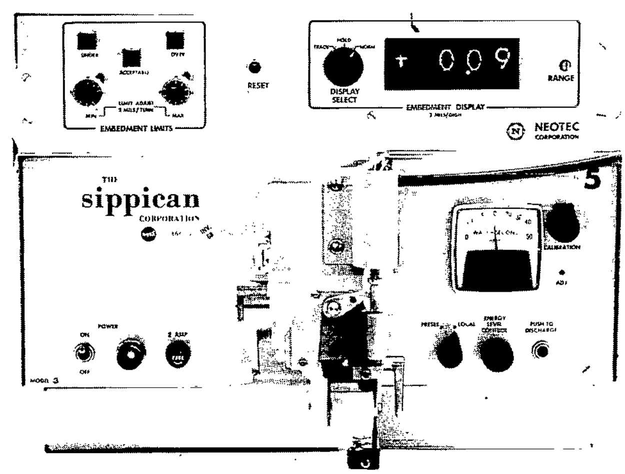


Figure 7—Weld quality monitor attached to opposed-electrode welding head.

CONCLUSION

The integrity of each welded joint produced on a production module can be monitored with the use of a device that automatically measures the change in embedment as the joint is produced. Optimum values of embedment can be determined for each combination of alloys and wire sizes through the development of strength-embedment data and standard deviation-embedment data.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, February 24, 1969
697-02-01-02-51

BIBLIOGRAPHY

Etzel, J., and Piltch, A., "Gage Monitors Quality of Cross-Wire Resistance Welds," NASA Tech Brief 68-10002.

Munford, J. A., "A Study of Embedment and Other Metallurgical and Mechanical Characteristics of Cross-Wire Resistance Welds," NASA Technical Note D-3714, November 1966.

"Technical Manual for Weld Monitor Model 270B," Neotec Corporation, Rockville, Md., March 1968.

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